Recall

If nonconservative forces do no work on a system, mechanical energy is conserved

$$E_{mech} = K + V = \text{const}$$

Recall

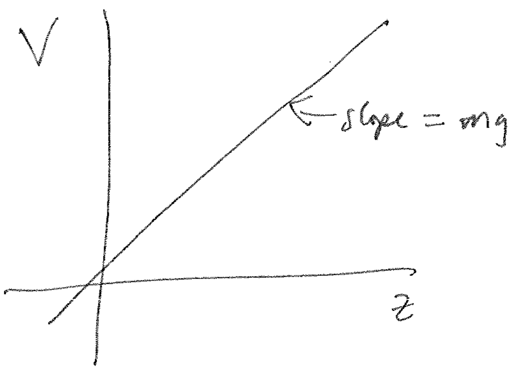
$$dV = -\vec{F} \cdot d\vec{r} = -(F_x\,dx + F_y\,dy + F_z\,dz)$$

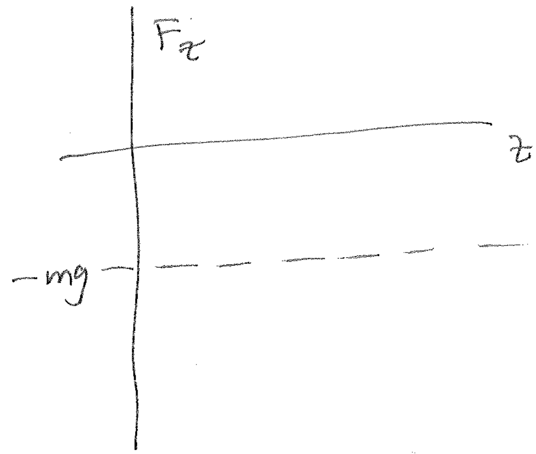
$$F_x = -\frac{dV}{dx}, \quad F_y = -\frac{dV}{dy}, \quad F_z = -\frac{dV}{dz}$$

force = − (slope of potential energy curve)

① gravity (near earth surface)

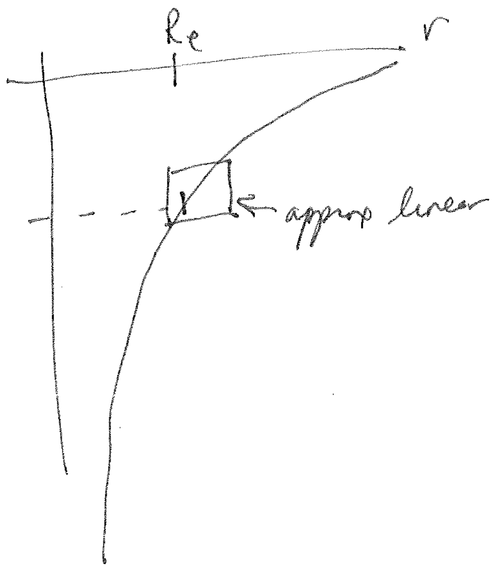
$$V = mgz \qquad F_z = -mg$$

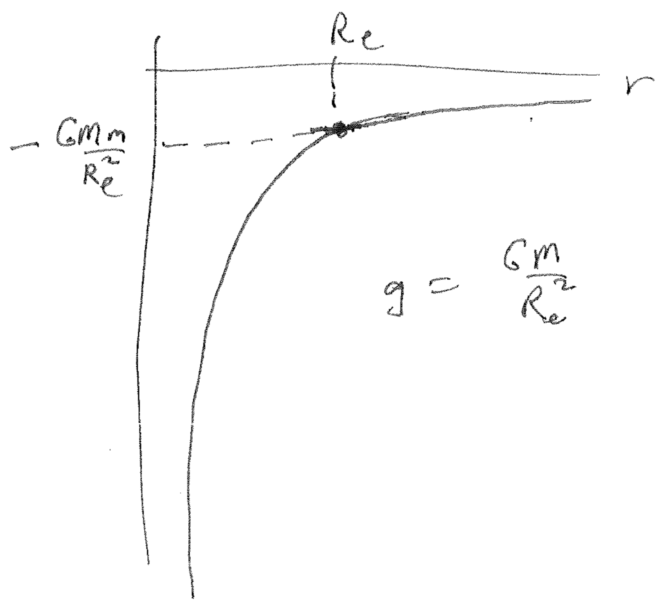




② universal law of gravitation

$$V = -\frac{GMm}{r} \qquad F = -\frac{dV}{dr} = -\frac{GMm}{r^2}$$





$$g = \frac{GM}{R_e^2}$$

③ electrostatic:

$$V = \frac{Kq_1q_2}{r}$$

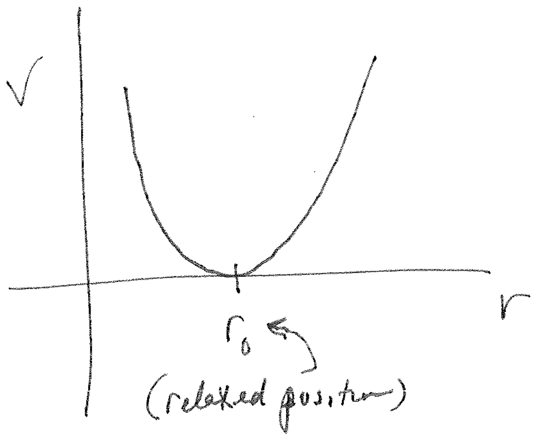
$$F_r = -\frac{Kq_1q_2}{r^2}$$

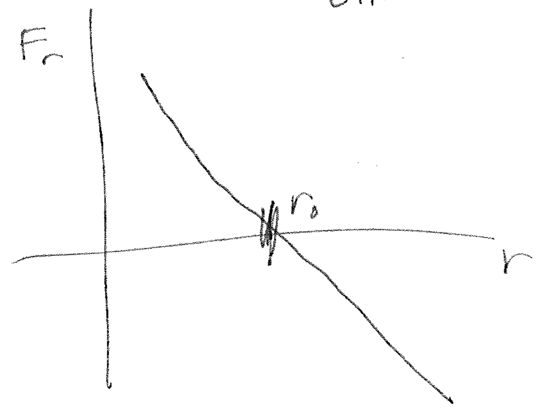
(4) spring force

$$V = \frac{1}{2} k_s (r - r_0)^2$$

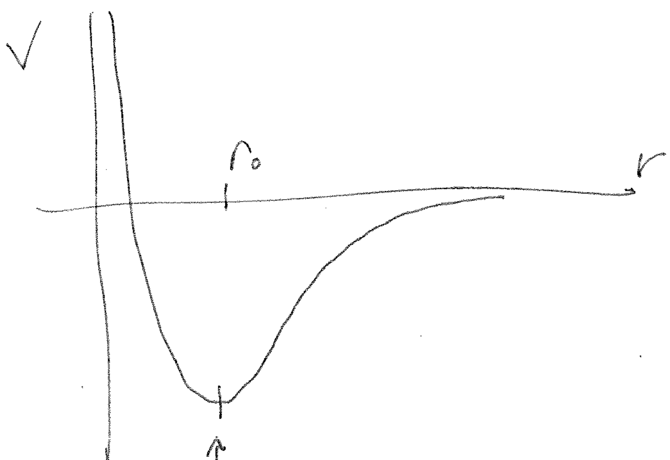
$$F_r = -k_s (r - r_0)$$

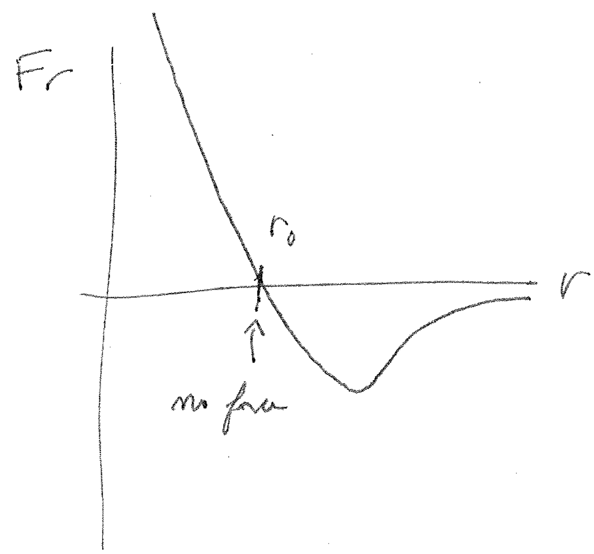
[Hooke's law]





(5) "typical" interatomic potential

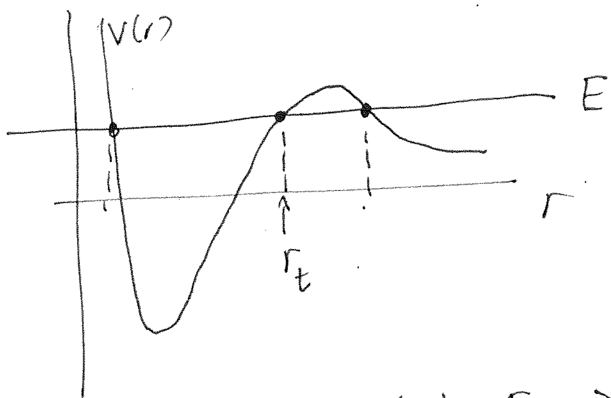




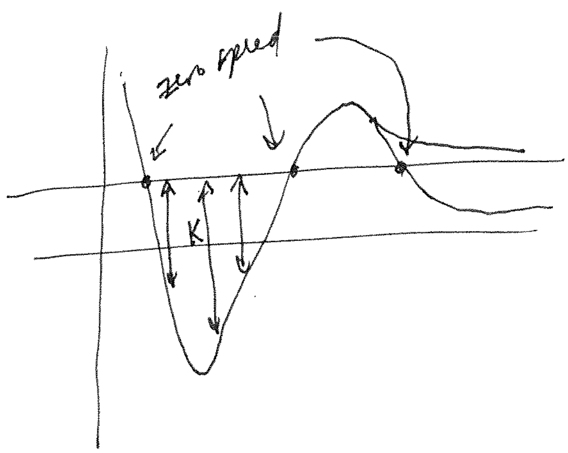
min of potential ⇒ zero slope ⇒ zero force ⇒ equilibrium position

$E = K + V$ = conserved (i.e. constant in time)

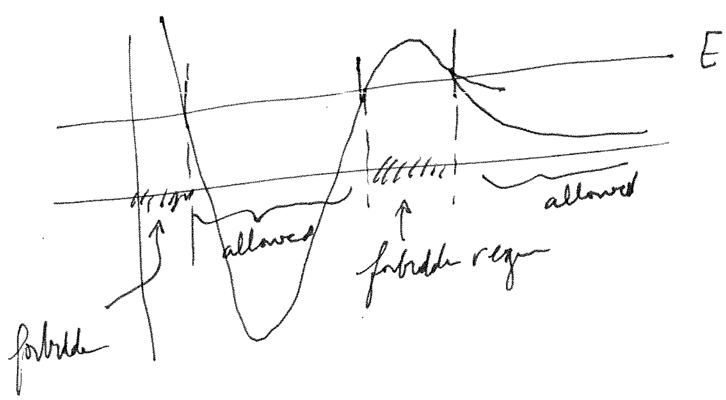
E is $\therefore$ independent of r $\Rightarrow$ horizontal line determined by initial conditions



At $r = r_t$, $V(r_t) = E \Rightarrow K = 0 \Rightarrow$ speed $= 0$ where ~~curves~~ E & $V(r)$ intersect



$K = E - V(r)$
Difference between E and $V(r)$ ~~[illegible]~~ is K.



Regions of r where $V(r) > E$ are forbidden!

Regions of r where $V(r) \leq E$ are allowed

r_t = "turning points"

[describe motion between turning points]

[C11.T8] E

[C11.T10] B

[C11.T11] A

[C11.T9] C

What is magnitude of force at 0.2 nm?

$$\sim \frac{15E-27 J}{0.1 nm} = 1.5E-10 N$$

other 2 minute q?

C11T.1 An object is free to move along the x axis. It is connected through two identical springs to two points $\pm y_0$ on the y axis. When the object is at $x = 0$, both springs are equally compressed. What kind of position is $x = 0$?
A. Unstable equilibrium.
B. Stable equilibrium.
C. Not an equilibrium position.

C11T.2 If your stove burner provides thermal energy at a rate of 4500 J/s, about how much water can you boil in a minute?
A. 2 kg
B. 120 kg
C. 0.002 kg
D. 0.12 kg
E. Other (specify)

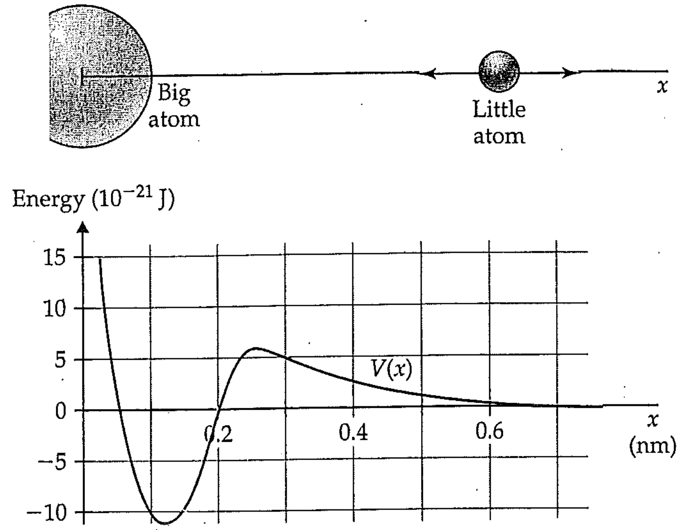
C11T.3 A 300-g hunk of ice at 0°C is placed in a thermos bottle containing 1 kg of water at 20°C. If the thermos perfectly insulates the ice-water system from the the system?
A. Below 0°C.
B. Almost exactly 0°C.
C. Somewhat above 0°C.
D. Very roughly 10°C.
E. Somewhat below 20°C.
F. Almost exactly 20°C.

C11T.4 The thermal energy of a block of ice at 0°C melting to a puddle of water at 0°C
A. Increases
B. Decreases
C. Doesn't change

C11T.5 An egg will not cook any faster in furiously boiling water than it will in gently simmering water, true (T) or false (F)?

C11T.6 A 100-g sample of a certain substance undergoes a transformation of some kind that releases about 20,000 J of energy. What kind of transformation is this likely to be?
A. A temperature change.
B. A phase change.
C. A chemical reaction.
D. A nuclear reaction.
E. It is impossible to guess.

C11T.7 If you were to climb about 10 stories worth of stairs, roughly what is the *minimum* number of food calories that you would have to burn? (Select the closest.)
A. 70,000 Cal
B. 4000 Cal
C. 70 Cal
D. 4 Cal
E. Less than 1 Cal



Problems C11T.8 through C11T.11 all refer to the situation in which two atoms interacting with each other have the potential energy shown in figure C11.5. You may assume that the massive atom's mass is much larger than the light atom's mass, the light atom can only move along the x axis, and $V(x) \to 0$ smoothly as $x \to \infty$.

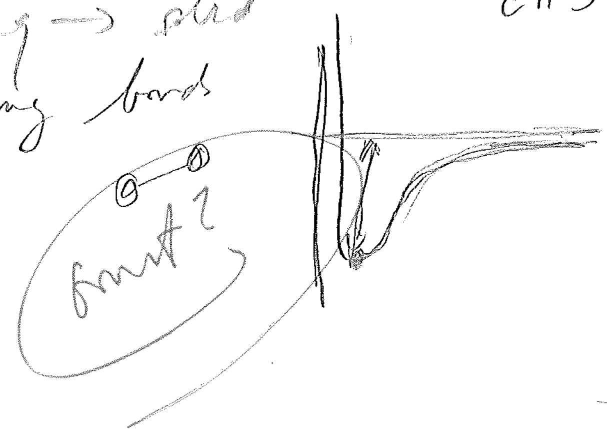
C11T.8 Imagine that the little atom approaches the big atom from infinity with an initial kinetic energy $K = 5 \times 10^{-21}$ J. How close to the big atom does it get?
A. $x = 0$
B. $x = 0.04$ nm
C. $x = 0.11$ nm
D. $x = 0.2$ nm
E. $x = 0.3$ nm
F. Other (specify)

C11T.9 Imagine that at a certain instant of time, the little atom is at position $x = 0.11$ nm and has a kinetic energy of 5×10^{-21} J. About how much energy would we have to add to break the bond?
A. 1×10^{-21} J
B. 6×10^{-21} J
C. 12×10^{-21} J
D. None: bond is already broken

C11T.10 Imagine that at a certain instant of time, the little atom is at rest at $x = 0.20$ nm. What is the closest that it will ever get to the big atom subsequently (in the absence of external effects)?
A. 0.03 nm
B. 0.05 nm
C. 0.20 nm
D. Other (specify)

C11T.11 If this system has a total energy of $+3 \times 10^{-21}$ J and the little atom is at $x = 0.11$ nm at a certain instant of time, the atoms are
A. Bound.
B. Unbound.
C. It depends on the little atom's initial direction of motion.
D. It depends on the little atom's initial speed.

phase changes : gas → liq → solid
due breaking / forming bonds



$\Delta U^{la} = mL$

boiling $L = 2.256 \times 10^{6} \frac{J}{kg}$ ~ 540 cal/g

freezing $L = 3.33 \times 10^{5} \frac{J}{kg}$ ~ 80 cal/g

thermal energy → microscopic kinetic eng
latent engy → " potential eng